

207 and heating member **205**, such that each radial segment is a wedge-shaped portion of a segmented cylinder. The radial segment may comprise a ceramic, such as alumina, silicon nitride, silicon carbide, zirconia, or the like. The radial segment may alternatively comprise a refractory metal, such as tungsten, molybdenum, or TZM alloy, or a cermet, such as Co-cemented tungsten carbide. The radial segments are enclosed within high strength enclosure **201**.

In a specific embodiment, a spacer, with a thickness between 0.001 inch and 0.1 inch, may be placed between successive rings in the stack to allow for thermal expansion. A sleeve may be placed around one or more ceramic rings. The sleeve may comprise steel or other suitable material according to a specific embodiment. The sleeve may be between 0.020 inch and 0.5 inch thick, and their height may be between 0.25 inch less than that of the ring and 0.1 inch greater than that of the ring depending upon the embodiment. Of course, there can be other variations, modifications, and alternatives.

In a specific embodiment, heater **105** or **205**, in apparatus **100** or **200**, respectively, comprises at least one hot zone and optionally more. Examples of suitable heaters are described in U.S. patent application 2008/0083741A1 and U.S. patent application Ser. Nos. 61/075,723 and 12/484,095, which are hereby incorporated by reference in their entirety.

In an embodiment, the capsule suitable for insertion inside the heater is formed from a precious metal. Examples of precious metals include platinum, palladium, rhodium, gold, or silver. Other metals can include titanium, rhenium, copper, stainless steel, zirconium, tantalum, alloys thereof, and the like. Examples of suitable capsules are described in U.S. Pat. No. 7,125,453 and in U.S. patent application Ser. No. 12/133,365, which are hereby incorporated by reference in their entirety.

A side view of apparatus **300** is shown in FIG. 3. The apparatus comprises a stack of two or more ring assemblies, comprising a high strength enclosure ring **301** and a ceramic ring **303**. The stack may include greater than 2, greater than 5, greater than 10, greater than 20, greater than 30, greater than 50, or greater than 100 ring assemblies. The stack surrounds heater **305** and capsule **307** and may be supported mechanically by at least one support plate (not shown). The stack may provide radial confinement for pressure generated within capsule **307** and transmitted outward through heater **305**.

Axial confinement of pressure generated within capsule **307** may be provided by end plugs **311**, end flanges **317**, and fasteners **315**. End plugs **311** may comprise zirconium oxide or zirconia. Alternative end plug materials may include magnesium oxide, aluminum oxide, silicon oxide, silicon carbide, tungsten carbide, steel, nickel alloys, salts, and phyllosilicate minerals such as aluminum silicate hydroxide or pyrophyllite according to a specific embodiment. End plugs **311** may be surrounded by end plug jackets **313**. End plug jackets may provide mechanical support and/or radial confinement for end plugs **311**. End plug jackets may also provide mechanical support and/or axial confinement for heater **305**. End plug jackets may comprise steel, stainless steel, an iron-based alloy, a nickel-based alloy, or the like.

End flanges **317** and fasteners **315** may comprise a material selected from a group consisting of steel, low-carbon steel, SA723 steel, SA266 carbon steel, 4340 steel, A-286 steel, iron based superalloy, 304 stainless steel, 310 stainless steel, 316 stainless steel, 340 stainless steel, 410 stainless steel, 17-4 precipitation hardened stainless steel, zirconium and its alloys, titanium and its alloys, and other materials commonly known as Monel®, Inconel®, Hastelloy®, Udimet 500®, Stellite®, Rene 41™, and Rene 88™.

Apparatus **300** may include a pressure transmission medium **309** proximate to the axial ends of capsule **307** and to end caps **311** according to a specific embodiment. The pressure transmission medium may comprise sodium chloride, other salts, or phyllosilicate minerals such as aluminum silicate hydroxide or pyrophyllite or other materials according to a specific embodiment.

The illustrated apparatus **300** can be used to grow crystals under pressure and temperature conditions desirable for crystal growth, e.g., gallium nitride crystals under related process conditions. The high-pressure apparatus **300** can include one or more structures operable to support the heater **305** radially, axially, or both radially and axially. The support structure in one embodiment thermally insulates the apparatus **300** from the ambient environment, and such insulation may enhance or improve process stability, maintain and control a desired temperature profile.

While the above is a full description of the specific embodiments, various modifications, alternative constructions and equivalents may be used. Therefore, the above description and illustrations should not be taken as limiting the scope of the present invention which is defined by the appended claims.

What is claimed is:

1. Apparatus for high pressure material processing comprising:

a cylindrical capsule region having a length;
a structure configured to provide axial confinement of pressure generated within the cylindrical capsule region;
an annular heating member enclosing the cylindrical capsule region; and

at least two assembled rings disposed around a perimeter of the annular heating member and configured to provide radial confinement for pressure generated within the cylindrical capsule region, each of the at least two assembled rings comprising a high strength enclosure ring surrounding an annular ceramic member having a thickness, the annular ceramic member being made of a material having a compressive strength of at least 0.5 GPa and a thermal conductivity of less than about 4 watts per meter-Kelvin;

wherein an interface between two adjacent assembled rings is located at a position along the length of the cylindrical capsule region.

2. Apparatus of claim 1 further comprising a capsule disposed within the cylindrical capsule region.

3. Apparatus of claim 2 wherein the capsule comprises a material selected from gold, platinum, silver, palladium, rhodium, titanium, rhenium, copper, stainless steel, zirconium, tantalum, and an alloy of any of the foregoing.

4. Apparatus of claim 2 wherein the capsule is characterized by a deformable material and is substantially chemically inert relative to reactants within the cylindrical capsule region.

5. Apparatus of claim 1 further comprising a cylindrical sleeve member disposed surrounding the annular ceramic member.

6. Apparatus of claim 5 wherein the cylindrical sleeve member is made of a material selected from stainless steel, iron, steel, iron alloy, nickel, nickel alloy, and a combination of any of the foregoing.

7. Apparatus of claim 1 wherein the structure configured to provide axial confinement comprises a first end flange and a second end flange.

8. Apparatus of claim 1 wherein the annular ceramic member has an inner diameter between 1.5 inches and 8 inches, a height between 0.5 inch and 8 inches, and an outer diameter,